Rib-Stiffened Composite Structure

Field of the Invention

The present invention relates to high stiffness, structural materials and more particularly to structural members comprising a sandwich of a multi-void between layers of high stiffness composite material.

Background of the Invention

Future generations of structural materials for use especially in aircraft and aerospace applications will require high temperature capability combined with high stiffness and strength while retaining and further minimizing weight. The use of plates and shells made from laminated composites, as opposed to monolithic materials, represents a dramatic increase in the airframe and aerospace designer's ability to meet ever-increasing structural requirements while minimizing weight. The use of composites, i.e. combinations of one material imparting strength or stiffness in a matrix of another material has been suggested and used in the design and fabrication of such plates and shells. Similarly, laminates incorporating composites adhered or otherwise attached to a core of a monolithic and dissimilar material have also been proposed. Since it is the outer layers of composite material in such laminates that are subjected to the highest tensile and compressive loading

in bending, it is possible to further dramatically increase the stiffness of a given plate or shell with very little increase in weight by using a sandwich structure. In the prior art, a typical sandwich structure consisted of two thin, high-strength face sheets bonded to a thick, lightweight core. The benefits of a sandwich structure are derived from the fact that the stiffness of any such laminated plate is a cubic function of its thickness. If the thickness of a given panel is doubled, its stiffness, or resistance to bending, increases by a factor of eight. If the increased thickness were achieved by doubling the thickness with additional composite layers, the weight of the panel would also double.

Current sandwich structures are typically manufactured from polymer-based composite thin face sheets with polymeric honeycomb cores. Most such honeycomb core used in the prior art comprises an adhesively bonded core that is subsequently bonded to face sheets to form a sandwich panel. Such structures are almost universally limited to low-temperature uses due to the use of adhesives and polymers in their structure.

Higher temperature applications require metallic cores, and preferably metallic composite skins. In the conventional practice, such metallic cores are fabricated by subjecting metal sheet to either a so-called “expansion” process or corrugation. The honeycomb structure is then fabricated by resistance welding skins to the “expanded” or corrugated core. This latter process is an intricate operation that adds significant cost to the finished product and, if not performed

totally correctly, i.e. every joint is adequately welded, the material can contain "defects" or discontinuities that weaken the structure considerably.

Thus, the availability of a high stiffness, high integrity yet lightweight structural material capable of elevated temperature application would be of significant advantage in the fabrication of airframe and aerospace structures.

Objects of the Invention

It is therefore an object of the present invention to provide an improved high-temperature-capable, high stiffness structural material.

It is another object of the present invention to provide such a material that exhibits a high degree of structural integrity.

It is yet another object of the present invention to provide such a material that demonstrates relatively reasonable fabrication costs when compared to prior art such materials.

Summary of the Invention

According to the present invention, there is provided a composite structural material sandwich comprising a multi-void core having layers of a stiffness

imparting composite material attached to both planar surfaces thereof. According to specifically preferred embodiments of the present invention, the multi-void core comprises an extruded metallic or polymeric material and the layers of stiffness imparting composite material comprise a metal matrix composite. According to a further preferred embodiment, the metal matrix composite includes ceramic fibers or particles that serve to stiffen and strengthen the "skin" material. A yet further highly preferred embodiment of the present invention utilizes a micro, multi-void extrusion as the core of the composite structure.

Description of the Drawings

Figure 1 is a cross-sectional view of a highly preferred embodiment of the composite sandwich of the present invention.

Figures 2 and 3 are perspective views of one fabrication apparatus useful in the manufacture of the composite sandwich of the present invention.

Detailed Description

Referring now to Figure 1, the composite sandwich of the present invention 10 comprises a multi-void core 12 having relatively thin "ribbons", tapes or layers 14 and 16 attached to the planar surfaces thereof. Multi-void core 12 includes voids 18 interspersed with stiffeners or ribs 20. Ribbons, tapes or layers 14 and 16 are

attached, according to the embodiment depicted in Figure 1, by intermediate attachment layers 22 and 24.

Core 12 may be fabricated from any of a large number of materials and by a variety of alternative fabrication methods. The most common technique is the extrusion of a metal such as aluminum or copper, or any of their various alloys, the former being preferred for lightweight applications. The manufacture of such multi-void structures is well known and practiced broadly in the aluminum and copper industries, such structures being commonly employed in a variety of heat exchanger applications such as automobile radiators and heater cores. In these industries, they are most commonly used to produce so-called "serpentine" heat exchangers.

Similar structures for core 12 can be fabricated from polymeric materials, especially engineering polymers such as polyimide and polyamide polymers and copolymers and mixtures of such polymers and similar materials. Such core structures are similarly generally produced by extrusion of the polymer at or near its softening point. Such practices are well known in the polymer extrusion industry and will not be further elaborated upon herein.

Yet a further modification of core 12 can include fabrication thereof using the well-known and widely practiced "pultrusion" process wherein a polymeric or metallic material is extruded simultaneously with the introduction of reinforcing

fibers of a ceramic or other high strength material. While cores produced in this fashion are generally inherently "stiff" as they emerge from the fabrication process, they are useful in flat panel production for applications where flat panels are the desired end product.

While a specifically preferred embodiment of the present invention utilizes so-called "micro", multi-void structures such as that depicted in Figure 1, it should be noted that the composition as well as the overall dimensions of core 12, voids 18 and stiffeners or ribs 20 as well as the thickness of layers 14 and 16 is largely a matter of design choice and dependent upon the designers selection of materials and sizes for a particular application.

Micro, multi-voids are commonly produced in widths from a few millimeters up to several inches and include any number of voids 18 depending upon the design of the end product to be fabricated therefrom.

The composition and dimensions of layers 14 and 16 are also largely a matter of design choice. These layers may comprise any suitable metallic or polymeric composite that imparts the desired stiffness to the final structure of sandwich 10 when assembled as described herein. As examples, metal matrix composites comprising a matrix of aluminum or one of its many alloys infiltrated/reinforced with, for example, ceramic fibers, filaments or particles such those of Al_2O_3, aluminum oxide, are useful in the successful application of the present invention.

Other suitable ceramic, glass and metallic fibers may be readily substituted in the metal/polymeric matrix materials useful in the successful practice of the present invention.

It should be noted that in its preferred embodiment, because of the fabrication procedures described hereinafter, it is preferred that both core 12 and layers 14 and 16 be separately "bendable" prior to attachment to provide the desired flexibility in the design and fabrication of structures from such materials. Also, because of their light weight and high strength aluminum alloys are preferred as the material for core 12 and aluminum metal matrix composites that include reinforcing fibers of ceramics are specifically preferred as the materials for layers 14 and 16.

Fabrication of one typical embodiment of composite sandwich 10 of the present invention would involve combining a commercially available of custom manufactured continuous fiber aluminum metal matrix unidirectional prepeg tape as layers 14 and 16 with a commercially available micro, multi-void aluminum extrusion core 12 manufactured by Thermalex, Inc., 2758 Gunter Park Drive, West Montgomery, Alabama 36109. In fabrication of this embodiment, the prepeg tape is placed on both sides of core 12 and attached via soldering, welding or brazing in the conventional fashion. Alternatively, the prepeg tape could be adhesively bonded to core 12. All of the just mentioned approaches: welding, soldering, brazing and

adhesive bonding, are specifically useful in the fabrication of composite sandwich 12, and may constitute layers 22 and 24 depicted in Figure 1.

As will be apparent to the skilled artisan, among the many advantages provided by the composite sandwich structure described herein are that the stiffness of the sandwich structure can be tailored to any particular application by adjustment of the thickness of core 12 or the thickness of layers 14 and 16. Similarly, custom orientation of layers 14 and 16 to optimize stiffness, strength or other properties in any particular direction based upon loading bearing requirements and/or conditions is possible.

Because of the continuous nature of the individual components of composite sandwich 10, core 12 and layers 14 and 16, it is possible to fabricate a wide number of shapes or structures from composite sandwich 10 when the individual elements, core 12 and layers 14 and 16 are untied or joined in the structure fabrication process.

One such fabrication process is depicted in Figures 2 and 3. According to this process, the fabrication of large aluminum metal matrix (AMC) structures is possible by the continuous brazing of aluminum matrix braze-clad tape as layers 14 and 16 to an aluminum micro, multi-void using an infrared laser to melt the braze clad on the tape while applying pressure to the tape and simultaneously contacting it with core 12 on a rotating mandrel. The apparatus utilized to accomplish this

fabrication process may include a variety of pre and post-contact heaters and may include instruments for the continuous monitoring and control of the process. Such a process is depicted schematically in Figures 2 and 3.

Referring now to Figures 2 and 3 wherein like numerals refer to like elements, an AMC braze-coated ribbon or tape 14 is applied about the periphery of a rotating/collapsible mandrel 30. As mandrel 30 rotates a continuous feed of core 12 is provided which is applied or brought into intimate contact with layer 14 by pressure wheel 32. Simultaneously with the application of core 12 to layer 14 by pressure wheel 32, the braze coating on the surface of layer 14 is exposed to coherent light from an infrared laser 34 emitting beam 36. The simultaneous application of pressure by pressure wheel 32 and heat by the action of beam 36 causes brazing/bonding to occur between layer 14 and core 12 thereby resulting in a single side application of layer 14 to core 12.

In a similar fashion, as depicted in Figure 3, single-side AMC coated core 38 resulting from the process depicted in Figure 3 is then treated to apply second layer 16 thereto. This is accomplished by rotating coated core 38 on mandrel 30 while bringing AMC prepeg tape or ribbon 16 into intimate contact with core 12 during the simultaneous application of pressure by pressure wheel 30 and heating of the braze coating on AMC prepeg tape or ribbon 16 by beam 36 generated by infrared laser 34. This causes AMC prepeg tape or ribbon 16 to join with core 30 by brazing of the two members together. The resulting structure is a laminated composite

sandwich having the shape of underlying mandrel 30. Such a structure can then be assembled with other similar or dissimilar, but similarly fabricated members to form a larger structure.

The forgoing, of course describes only one possible fabrication technique for the manufacture of composite sandwich structures of the type described herein and numerous other similar or dissimilar but equally useful techniques can easily be envisioned by those skilled in this art.

Composite sandwiches of the type described herein have many applications. Primarily, they are useful in the production of high stiffness, low-density composite structures. Panels or other structures manufactured from appropriate materials, e.g. aluminum alloys, as described herein retain their stiffness up to about 700°F. In addition, the continuously open spaces created by voids 18 provide many alternative design possibilities. For example, composite sandwich 10 could be used as the shell for cylinders containing cryogenic fluids and voids 18 used to pass coolant through core 12 to maintain proper internal temperatures.

The structure described herein could also be used for the construction of electronics housings, with each of voids 18 serving as a conduit for coolant to maintain controlled temperature environments in, for example, satellites.

Since each of voids 18 in an aluminum multi-void as described can typically contain compressed gas at a pressure of about 600 psi, inflating the panel can further increase its stiffness, or alternatively, voids 18 can be used to contain and transport some volume of compressed gas.

Voids 18 also provide the means to easily pass various sensors such as acoustic emission sensors or thermocouples thus allowing for the construction of "smart" panels that incorporate both sensors for detecting "out of control" conditions while simultaneously providing passages for the conduction of heating or cooling media to a particular location within the structure, or as a condensor or evaporator for similar purposes.

As the invention has been described, it will be apparent to those skilled in the art that the same can be varied in many was without departing from the spirit and scope of the invention. Any and all such modifications are intended to be within the scope of the appended claims.